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(54) **CALL ADMISSION CONTROL AND PREEMPTION CONTROL OVER A SECURE TACTICAL NETWORK**

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H04L 12/801	(2013.01)
H04L 12/54	(2013.01)
H04L 12/851	(2013.01)

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(58) **Field of Classification Search**
CPC H04L 47/245; H04L 47/00–47/135; H04L 47/70–47/745; H04L 12/5695
USPC 370/229–240
See application file for complete search history.

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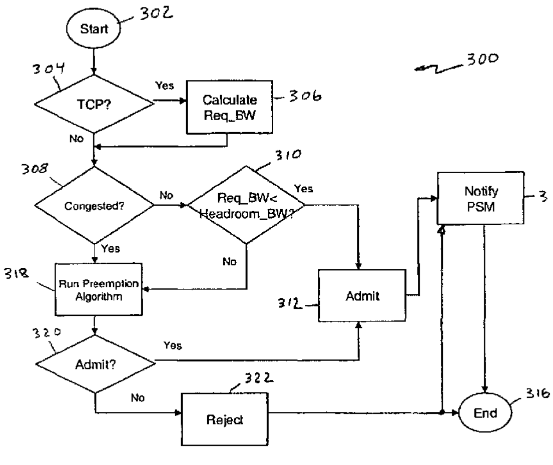
(57) **ABSTRACT**

In a secure network where the network characteristics are not known, a call admission control algorithm and a preemption control algorithm based on a destination node informing the source node of the observed carried traffic are used to regulate the amount of traffic that needs to be preempted by the source. The amount of traffic that needs to be preempted is based on the carried traffic measured at the destination node. The traffic to be preempted is based on the priority of the traffic, where the lowest priority traffic is the first to be preempted until the amount of traffic preempted is sufficient to allow the remaining traffic to pass through the network without congestion.

7 Claims, 4 Drawing Sheets



(51) **Int. Cl.**

H04L 12/927	(2013.01)
H04L 12/911	(2013.01)

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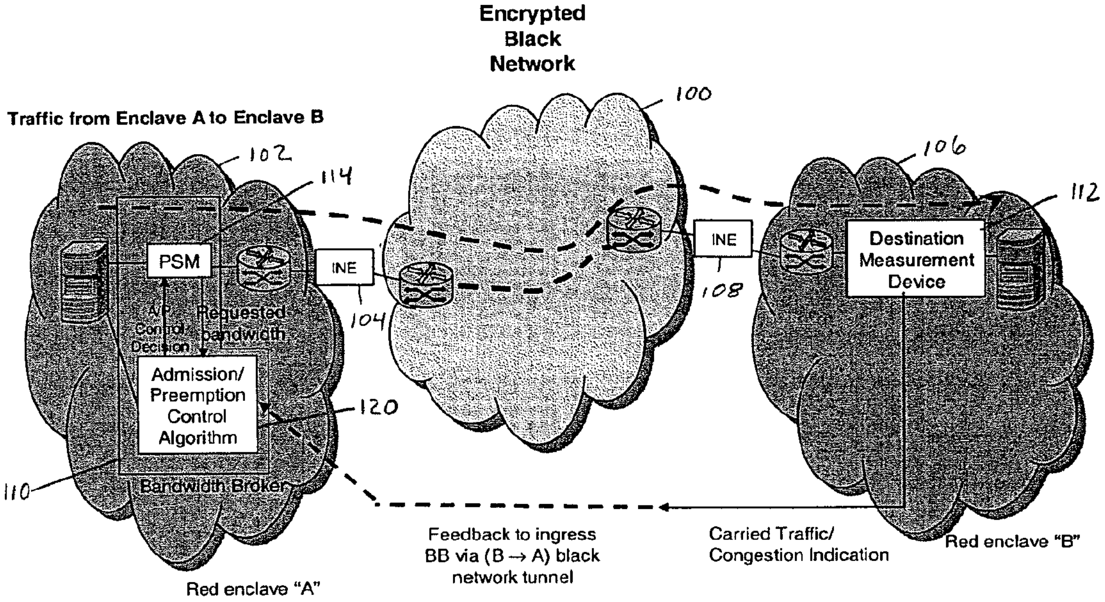
Encrypted
Black
Network
100
Traffic from Enclave A to Enclave B
102
114
106
112
PSM
INE
INE
Destination
Measurement
Device
104
108
A/P
Control
Decision
Requested
bandwidth
Admission/
Preemption
Control
Algorithm
120
110
Bandwidth Broker
Feedback to ingress
BB via (B → A) black
network tunnel
Carried Traffic/
Congestion Indication
Red enclave "B"
Red enclave "A"

FIG. 1

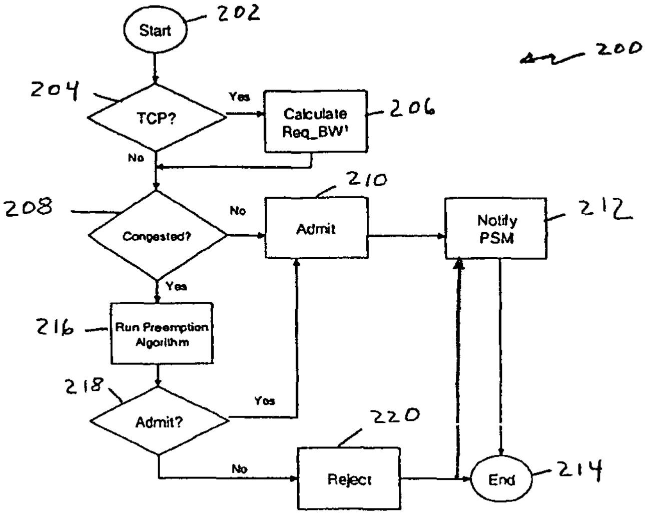
Start
202
200
204
TCP?
Yes
Calculate Req_BW'
206
No
210
208
Congested?
No
Admit
Notify PSM
212
Yes
216
Run Preemption Algorithm
218
Admit?
Yes
220
No
Reject
End
214

FIG. 2

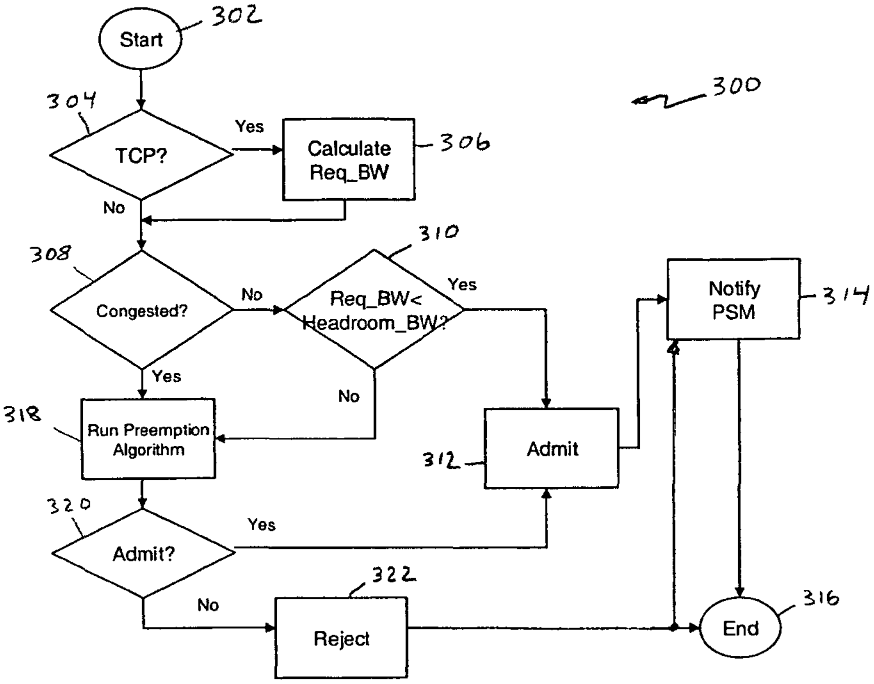
302
Start
300
304
TCP?
Yes
Calculate Req_BW
306
No
310
308
Congested?
No
Req_BW< Headroom_BW?
Yes
Notify PSM
314
Yes
No
318
Run Preemption Algorithm
312
Admit
320
Admit?
Yes
322
No
Reject
316
End

FIG. 3

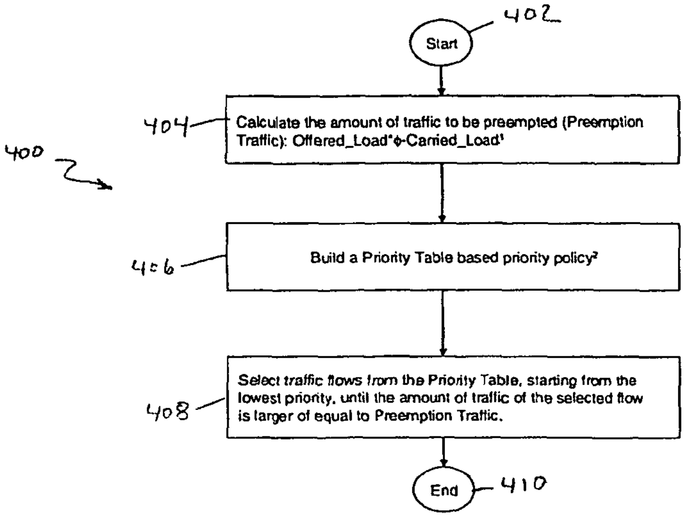
402
Start
404
Calculate the amount of traffic to be preempted (Preemption Traffic): Offered_Load*ϕ-Carried_Load¹
400
406
Build a Priority Table based priority policy²
408
Select traffic flows from the Priority Table, starting from the lowest priority, until the amount of traffic of the selected flow is larger of equal to Preemption Traffic.
End
410

FIG. 4

CALL ADMISSION CONTROL AND PREEMPTION CONTROL OVER A SECURE TACTICAL NETWORK

RELATED APPLICATIONS

This application is a continuation application of U.S. patent application Ser. No. 11/116,512, filed on Apr. 28, 2005, which is incorporated by reference in its entirety herein.

GOVERNMENT LICENSE RIGHTS

This invention was made with Government support under DAAB07-01-C-L534 awarded by U.S. Army-CECOM. The Government has certain rights in this invention.

FIELD OF THE INVENTION

The present invention relates generally to management of the quality-of-service and access control of the network backbone in a secure wireless network. Specifically, the invention concerns call admission control and preemption control over a secure tactical network.

BACKGROUND OF THE INVENTION

In a secure tactical network there are a number of access networks interconnected by an encrypted backbone. Information exchange is not allowed across the access and backbone boundary. In order to manage the quality of service, controlling access to the backbone, which is often limited in bandwidth resource, is needed.

Military wireless networks carrying heterogeneous traffic with multiple levels of survivability present a challenging admission control problem. These unique challenges include: encryption boundaries that prevent communicating the state information known on the WAN (backbone) side to the LAN where admission control is implemented; and the capacity of wireless links that can change with time (fading or mobility) that cause the available network resources between a source node and a destination node to fluctuate requiring an adaptive admission technique that avoids overloading the wireless links.

In one prior art solution to the problem, the General Dynamics Corporation C4S's Measurement Based Admission Control (MBAC), a feedback mechanism is used in which a congestion indicator, identified as "severity level", is sent from the destination to the source to regulate traffic. However, the severity level alone is insufficient for the source to adequately regulate the network traffic. The severity level is used to allow the source to infer the congestion status and then to determine the calls that belong to a particular DSCP (Differentiated Services Code Point) to preempt. This approach is only a first step for regulating traffic into the network. The congestion level is not a critical piece of information for the source. The amount of traffic that has to be preempted is the most important information to the source. Often, due to a lack of precise information with regard to how much traffic needs to be preempted, or how much bandwidth is still available, the MBAC framework relies on a "trial-and-error" technique, making the method very slow to react.

One of the main features of the invention is the intelligent usage of the available bandwidth estimates of a tunnel across a black network, while the network is congested. "Available bandwidth" is defined as the amount traffic that has been successfully sent, or equivalently, the carried traffic. A "tunnel" is defined as a pair of source and destination red enclaves which send and receive traffic to and from the black network. These bandwidth estimates are used by the Call Admission Control (CAC) engine to regulate traffic into the tunnel. A "black network" as used herein is a secure (encrypted) wireless network that handles encrypted traffic.

When the tunnel is under-loaded, i.e. the offered traffic is less than the maximum amount of traffic the tunnel can carry, if the "headroom bandwidth" of the tunnel, which is defined as the amount of bandwidth that can be used by new traffic, is available through estimation techniques, the CAC engine can selectively admit forthcoming traffic into the network without overloading the black network while protecting the higher priority traffic. If the "headroom bandwidth estimate" is not readily available to the CAC engine, the calls can be admitted into the network, and the second part of the framework, which deals with overload conditions, will be triggered to force the system into a stable state in a speedy manner.

The presence of cross-over traffic which is originated and admitted from other nodes into the network and utilizes the same bottleneck link or degraded RF conditions can cause the tunnel to be congested or overloaded. When overload occurs, the amount of offered traffic injected into the tunnel is larger than the amount of traffic the tunnel can carry. In accordance with the teachings of the present invention, the amount of carried traffic is measured and provided to the CAC engine. The CAC engine selectively preempts the appropriate flows to ease the overload condition, in a manner such that higher priority traffic flows are protected.

There still exists a need for call admission control and preemption control over a secure tactical network where a source node located in the LAN transmits packets through a secure black backbone (WAN), in which data are encrypted, to a destination node located in another LAN. Due to security concerns, there is virtually no information about the WAN that can be sent to the source or destination nodes. Accordingly, it is very difficult to manage the end-to-end Quality-of-Service in this type of network architecture. The present invention provides a solution to overcome this problem.

In order to overcome the limitations found in the prior art and to improve the network performance the present invention provides a method so that source is aware quantitatively of the amount of traffic that needs to be preempted during periods of congestion.

SUMMARY

The present invention calculates the amount of traffic that needs to be preempted by the source. Preemption of calls is necessary to ensure that the remaining calls have a satisfactory Quality-of-Service (QoS) and the number of calls to be preempted is determined by the congestion level as well as the requested bandwidth of the existing calls. The present invention solves the problem by use of a call admission algorithm and a preemption algorithm based on the destination node informing the source node of the observed carried traffic. The source node is informed of the amount of traffic that needs to be preempted. Using this crucial information, the source can quickly and precisely move the network operation to the correct "operating point". The novel algorithms result in improved throughput (the number of calls that can be supported) performance.

A principal object of the present invention is therefore, the provision of a novel method and system for improving throughput performance of a network.

Another object of the present invention is the provision of a call admission control algorithm for measuring the traffic into and out of network and preempting traffic when the network is congested.

A further object of the invention is the provision of a preemption control algorithm for preempting traffic based on network congestion and available bandwidth into and out of the network.

Further and still other objects of the present invention will become more clearly apparent when the following description is read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic block diagram of a red/black network using destination control.

FIG. **2** is a flow chart of a bandwidth estimation algorithm and a call admission control algorithm without headroom bandwidth estimate information.

FIG. **3** is a flow chart of a bandwidth estimation algorithm and a call admission control algorithm with headroom bandwidth estimate information.

FIG. **4** is a flow chart of a preemption control algorithm.

DETAILED DESCRIPTION

Referring now to the figures and to FIG. **1** in particular, there is shown a schematic block diagram of a typical battlefield red/black network using destination measurement. In FIG. **1** the backbone (black) network **100** is a secure (encrypted), wireless network. At the access red enclave "A" network **102**, and black network **100** tunnel ingress point and at the red enclave "B" network **106** and black network **100** tunnel egress point, there are respective encryption devices (In-line Network Encryptor) **104**, **108**. A standard bandwidth broker (BB) structure **110**, i.e. before sending traffic into the black network, an application in the red enclave "A" or network **102** makes a request to the BB for the amount of bandwidth needed. The BB runs a call admission control algorithm **120** to determine if the call can be admitted.

Red enclave "A" **102** and red enclave "B" **106** are typically wired-line networks, and both are physically confined in a controlled area (e.g. a division headquarter). Hence, there is typically no need for encryption for traffic flowing within the red enclaves. When data needs to be transmitted from one red enclave to another distant red enclave, the data is typically sent over a wireless medium which is subject to hostile enemy interception and jamming. Therefore, right before data is sent over the wireless medium, for example when traffic is being sent from enclave "A" to enclave "B", the data is encrypted using an encryption device (Inline Network Encryptor (INE)) **104**, such as a HAIPE (High Assurance Internet Protocol Encryptor) device At the receiving end, the data is decrypted by decryption device **108**, such as a HAIPE device, and sent into the secure destination red enclave "B" **106**. The encrypted network **100** between two encryption devices is usually referred as the "black network".

The wireless black network **100** has only wireless links with limited bandwidth and very dynamic characteristics, i.e. the bandwidth of a wireless link can experience tremendous fluctuations due to adverse RF conditions and/or jamming. Modern military operations demand a sophisticated Quality-of-Service (QoS) management regime to satisfy the underlying diverse loading profile (i.e. voice, data and video, etc), QoS requirements and priority management (e.g. MLPP (Multi-Level Precedence and Preemption)) However, due to security concerns, there is virtually no information about the black network that can be sent across the encryption device into the red enclaves. Hence, the black network has to be treated by the red enclaves as a true "black box". These considerations make the QoS management over the red/black network very challenging.

In an effort to devise a comprehensive solution for providing adequate QoS control over the red-black network a Destination Measurement Device **112** is deployed. The Destination Measurement Device **112** uses the observations from the QoS attributes of the live traffic that are collected at the destination red-enclave to compute the carried traffic per DSCP. These carried traffic observations are then processed for call admission control. The algorithms implemented in the Destination Measurement Device **112** assume no knowledge about the black side network characteristics (e.g. topology, link BW, router configuration, etc).

In the case of packets sent from red enclave "A" **102** to red enclave "B" **106** through black network **100**, before leaving the source red enclave "A" **102** an ingress time stamp and a packet sequence number are written into data packets by the PSM (Policer/Shaper/Marker) device **114**. At the destination enclave "B" **106**, using the ingress time stamp the per packet end-to-end delay is obtained. The end-to-end delay and the packet sequence number are then used as input data for Destination Measurement Device **112**.

Destination Measurement Device **112** has two main functionalities. First, it estimates the carried traffic, i.e. the amount of traffic that has been successfully sent through the black network, or the available bandwidth. Secondly, it detects if the tunnel is in a congested state, by comparing the observed packet loss and packet delay with a set of preset thresholds.

The algorithms may be stored in a memory device and used by a computing device to run the algorithms in conjunction with a communications system.

The results obtained from Destination Measurement Device **112** are provided back to the BB **110** for Call Admission Control and Preemption Control **120**. Before traffic is sent into the black network **100**, a request is made BB **110**. Based on the results from the Admission/Preemption Algorithm **120** the call is either admitted or denied by BB **110**. In addition, for flows that have already been admitted, based on the feedback from Destination Measurement Device **112**, the Admission/Preemption Algorithm **120** may preempt some of the calls in order to protect higher priority traffic.

Admission/Preemption Control algorithm **120** will now be described in detail.

FIG. **2** is a flow chart of a call admission control (CAC) algorithm **200**, assuming no headroom bandwidth estimate is available. That is, the CAC algorithm examines whether the network is already in a congested mode using feedback from Destination Measurement Device **112**. If the network is not in a congested mode the call is admitted. Otherwise, a preemption control algorithm **120** is run to see if some of the existing lower priority calls need to be preempted to accommodate the new call. The preemption control algorithm is shown in FIG. **4**.

The call admission control algorithm **200** starts **202** and a determination, is made whether the requesting call uses TCP (Transmission Control Protocol) **204** If yes, there is a calculation of the required bandwidth **206**. The required bandwidth is the file size divided by the speed of service multiplied by θ, which is a tunable parameter, Req_BW=File_size/Speed-of-Service*θ. If the requesting call uses UDP (User Datagram Protocol), the requested bandwidth is the encoding rate of the coder, and no calculation is needed.

After calculating the required bandwidth or if not using TCP, determine if the network is congested **208**. If the network is not congested, admit the call **210**, notify the PSM **212** and end the algorithm **214**.

If the network is congested, run the preemption algorithm **216** (**400**). Then, decide whether the call should be admitted **218**. If so, admit the call **210** and notify the PSM **212** and end the algorithm **214**. If after running the preemption algorithm **216** it is decided that the call should not be admitted, reject the call **220**, notify the PSM **212** and end the algorithm **214**.

FIG. **3** is a flow chart of a call admission control algorithm in which the headroom bandwidth estimate data is available. In this case, the CAC algorithm portion checks if the headroom bandwidth is large enough to admit the new call. If not, the preemption algorithm is run such that some of the lower priority calls are preempted.

The Call Admission Control algorithm **300** starts **302**. A determination is made whether TCP **304** is used. If yes, calculate the required bandwidth **306**.

After calculating the required bandwidth or if the TCP is not used, determine if the network is congested **308**. If the network is not congested, calculate if the required bandwidth is less than the headroom bandwidth multiplied by η which is a tunable parameter **310**. That is, Req_BW<Headroom_BW*η. If the required bandwidth is less than the headroom bandwidth multiplied by η admit the call **312**, notify the PSM **314** and end the algorithm **316**.

If the network is congested or if the required bandwidth is not less than the headroom bandwidth multiplied by η, run the preemption algorithm **318**. After running the preemption algorithm, decide if the call should be admitted **320**. If yes, admit the call **312**, notify the PSM **314** and end the algorithm **316**. If the call is not admitted, reject the call **322**, notify the PSM **314** and end the algorithm **316**.

FIG. **4** is a flow chart of a preemption algorithm. The preemption algorithm **400** can be triggered by CAC when checking if some of the existing low priority calls can be preempted while network is in congested state (steps **216** and **318**). The preemption algorithm **400** can also be triggered independently from CAC: when the congested state is declared, preemption algorithm **400** is triggered to preempt low priority calls to protect the high priority traffic. Network congestions can be declared by Destination Measurement Device **112** through QoS measurements (delay, loss, jitter, etc.) exceeding preset thresholds. The preemption algorithm comprises two major steps: determining the amount of the traffic that needs to be preempted **404** and building a priority table **406** (the priority of various calls is determined according to a network policy). The former is the key to obtaining good performance: the amount of the traffic needs to be decided by examining the offered and carried traffic. In FIG. **4**, the weighted difference between offered and carried traffic is used to determine the preemption traffic amount. After preemption traffic is determined, individual calls are preempted, starting from the lowest priority calls in the priority table.

The preemption algorithm starts **402** and a calculation is made of the amount of traffic that is to be preempted **404**. The preempted traffic is Offered_Load*Φ−Carried_Load, where Offered_Load is obtained from the requested bandwidth from the existing calls, and Φ is a tunable parameter. If the preemption algorithm is called from the CAC, the preemption traffic is Req_BW.

Next, a priority table is built **406** based on a priority policy. An example of a priority table is Offered_load, Carried_load and Preemption Traffic calculated per class. Priority Tables are also built per class based on DSCP precedence. Another example of a priority table is Offered_load, Carried_load and Preemption Traffic calculated per tunnel across classes. The priority across classes is determined by policy (e.g., Precedence “Regular” of AF2 has a higher priority than Precedence “Regular” of EF).

Traffic flows are selected from the Priority Table **408** starting from the lowest priority, until the amount of traffic of the selected flow is equal to or greater than the preemption traffic. Then, the preemption algorithm ends **410**.

While the invention has been described in conjunction with a secure (encrypted) network, the invention is applicable to any network through which traffic passes along a path from a source node to a destination node when the characteristics of the network, such as but not limited to topology, link bandwidth, router configuration, etc., are not known.

Having described and illustrated a method and system for improving throughput performance of a network, it will be apparent to those skilled in the art that variations and modifications are possible without deviating from the broad principles and teachings of the present invention which shall be limited solely by the scope of the claims appended hereto.

What is claimed is:

1. A method comprising:

determining whether data traffic is using Transmission Control Protocol (TCP);

in response to determining that the data traffic is using TCP:

calculating a required bandwidth for sending the data traffic to a destination through an encrypted network with a call admission control and preemption control; and

determining with the call admission control and preemption control whether to admit or deny data traffic into the encrypted network based at least in part on a carried traffic per differentiated services code point (DSCP) calculated and provided by a destination measurement device located at the destination to the call admission control and preemption control, wherein the calculated carried traffic per DSCP is based on information regarding data traffic received at the destination from a source over the encrypted network, wherein the information comprises at least one of an ingress time stamp of received packets or a packet sequence of received packets;

wherein all parameters of the encrypted network are unknown to the destination measurement device and the call admission control and preemption control, except via the information received by the destination measurement device at the destination regarding at least one of the ingress time stamp of the received packets or the packet sequence of the received packets.

2. The method of claim **1**, wherein, in response to determining to deny data traffic into the encrypted network, determining the quantity of the data traffic that has to be preempted comprises:

calculating the quantity of data traffic to preempt,

building a priority table prioritizing the data traffic attempting admission into the encrypted network, and preempting data traffic according to the lowest priorities in the priority table until the determined quantity of data traffic is preempted.

3. The method of claim **1**, wherein said calculated required bandwidth for TCP traffic, Req_BW, is File_size/ Speed-of-Service* θ, where File_size is the size of the file that needs to be sent via TCP, Speed-of-Service is the required amount of time the file transmission needs to be completed in and θ is a tunable parameter.

4. The method of claim **3** further comprising notifying a Policer/Shaper/Marker of the admitted data traffic.

5. The method of claim **3** further comprising notifying a Policer/Shaper/Marker of rejected data traffic.

6. The method of claim **1**, wherein the determination whether to admit or deny data traffic into the encrypted network is determined based upon an analysis of quality of service measurements for existing data traffic, said quality of service measurements are compared with preset threshold values.

7. A non-transitory computer readable medium, having instructions stored thereon that, in response to execution by a device, cause the device to perform operations comprising:

determining whether data traffic is using Transmission Control Protocol (TCP);

in response to determining that the data traffic is using TCP:

calculating a required bandwidth for sending the data traffic to a destination through an encrypted network with a call admission control and preemption control; and

determining with the call admission control and preemption control whether to admit or deny data traffic into the encrypted network based at least in part on a carried traffic per differentiated services code point (DSCP) calculated and provided by a destination measurement device located at the destination to the call admission control and preemption control, wherein the calculated carried traffic per DSCP is based on information regarding data traffic received at the destination from a source over the encrypted network, wherein the information comprises at least one of an ingress time stamp of received packets or a packet sequence of received packets;

wherein all parameters of the encrypted network are unknown to the destination measurement device and the call admission control and preemption control, except via the information received by the destination measurement device at the destination regarding at least one of the ingress time stamp of the received packets or the packet sequence of the received packets.

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